Feature by David Beard G8FMX

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A Remote-Controlled Homebrew Screwdriver Antenna Part 1

David Beard G8FMX describes how to homebrew the popular Screwdriver antenna, suitable for fixed or portable operations.

The Screwdriver antenna was originally the brainchild of the late Don Johnson W6AAQ, who was regarded as a legend in amateur HF mobile circles. He described it as a *"continuously tuneable high performance HF mobile antenna with no coil taps and a* Q *that remains reasonably high over the entire tuning range"*.

The key to the Screwdriver antenna's construction is the variable inductor, which is adjusted by raising or lowering it within a metal base tube by means of a motor-powered threaded rod. The motive power is supplied by a commonly available cordless screwdriver motor, hence the name. The top of the base-tube makes contact with the coil turns by means of a springy fingerstock and only the section of coil above this point is in circuit, providing resonance at a given frequency dependent on the number of turns exposed. The coil turns below the fingerstock are out of circuit within the base tube. By a combination of adjustment of this inductor and the length of the whip section above it, the antenna can be resonated between about 3.5 and 50.2MHz. As a bonus, control of the antenna's motor and the base-matching inductor tap-point is performed remotely using one of the commonly available wireless remote units that are otherwise popular for controlling domestic lighting, audio equipment, garage doors and the like.

Although there are a few excellent constructional articles for this antenna (see, for example, the *ARRL Antenna Handbook*, 23rd edition, Chapter 21 in Supplemental Files), they are challenging for the average constructor because access to a screw-cutting lathe is required to place grooves on the coil former at the correct pitch to hold the windings. The construction method employed here circumvents that requirement and results in a properly spaced and serviceable inductor of robust construction. Instead of indenting a groove in the coil former, the turns are securely held in place with polypropylene cord squashed between the turns providing correct spacing with no marked detrimental effects on efficiency. Originally designed for mobile use, this antenna can be equally effective as a portable unit or in a fixed installation where space is at a premium.

The remote controlled Screwdriver antenna as described is constructed from readily sourced or home-built materials and for well under £100.

Construction Materials and Tools

All materials and tools used in the antenna's construction are listed in the sidebar and are readily available. The list includes suggested sources.

Constructing the Loading Inductor

If you are fortunate enough to have access to a screw-cutting lathe or pipe-threader, then use the tool to cut a shallow spiral along the tube for about 500mm. There should be eight to nine turns per inch although this is not critical. Use a wooden mandrel through the PVC tube to keep it rigid while cutting. For those who do not have access to a lathe, a perfectly serviceable alternative is to intersperse the coil turns with 2mm diameter polypropylene cord, as mentioned above.

Take your time and work methodically. Take a 600mm length of PVC pipe or electrical conduit, 35mm diameter

Fig. 1: The completed coil.

Fig. 2: Coil top coupling detail.

(not critical) and square off the ends accurately in a mitre block. Drill a 1.5mm hole about 50mm down from the top with a second 2mm hole adjacent to it. Drill two further holes as before about 25mm up from the other end. The coil is wound with 16SWG tinned copper wire over a length of about 500mm. Insert the wire through the first hole at the top and wind it round a small bolt so that it can't slide out. Ensure there is enough wire protruding to make a connection later.

Wind on fairly tightly about 180 turns then cut the wire a further 350mm along. Pass this end through the first hole at the lower end of the tube. The turns should remain fairly tight but movable. Go back to the top and thread the polypropylene cord through the other hole, securing it so it won't pull out. Now carefully wind the cord between each of the wire turns, pushing and twisting the coil turns up against the cord. Make sure that the cord doesn't slip under the wire; it should lie neatly between the turns and keep them tightly in place. You may need to add or remove a few turns of wire as you reach the lower end. Once complete you should end up with a neat, tight coil evenly spaced at about 9tpi (turns per inch) as shown in **Fig. 1**.

Pass the wire and cord through their respective holes at the end of the tube and secure tightly, cutting off and securing surplus cord. Cut the wire short and make a tight finish that cannot pull out. This end of the coil is left unconnected.

The coil former now needs to be fitted at each end with plugs to take the whip attachment at the top and the Allthread rod at the base. I made the plugs from nylon kitchen cutting board (not the XYL's of course!). Ideally, this board needs to be about 10mm thick and can be cut using a hole borer, the sort with a drill bit through the centre, which has the advantage of placing a pilot hole in the dead centre of the plug. Alternatively, the plug can be cut out quite easily with a fretsaw then filed to fit the tube tightly. When you are happy with the fit of the top plug, check that it's flush with the top of the coil former and drill four equally spaced fixing holes (2 to 3mm) through the coil former and into the edge of the plug for about 10mm. Countersink the entry points by hand with a large drill bit for later flush fitment of retaining screws. These can be short, brass countersunk woodscrews. But first, the plug has to be fitted with some brass plumbing!

The nylon plug at the top end of the coil carries a 15mm to 10mm reducer (straight compression joint). Open out the hole in the centre of the nylon plug wide enough to allow the narrow end of the reducer to pass through. Cut away the underside of the plug if required so that the nut goes on the thread. Cut the pigtail at the top of the coil winding, just below the top of the former, and solder flexible wire to it. Connect the free end to a solder tag held in place with an M4 screw, drilled and tapped on the smaller end of the brass fitting. Attach the nut onto the brass fitting and tighten so you have the nylon plug sandwiched, see **Fig. 2**. Insert the plug into the top of the coil former, lining up your fixing screw holes and secure with four short brass countersunk screws. You should now have a closed end with the top of the coil internally connected to the brass fitting. Outside, the 15mm end of the brass fitting is uppermost, aligned centrally and ready to fit the first section of the 'whip' (copper tube).

Construction Materials and Tools

All materials used in the antenna's construction are readily available from sources and outlets listed below.

B&Q or other DIY outlet:
PVC pipe (for coil former) and 6mm Allthread rod.
15mm copper pipe and two straight brass compression joints.
Two 15mm to 10mm reducers.

eBay:
2mm diameter polypropylene cord.
Aluminium tube, acrylic (cover) tube.
Beryllium-copper fingerstock (optional).
600 x 600 x 3mm aluminium plate.
4-channel wireless remote control unit and key fob.
14SWG aluminium florists' wire.
Old cordless screwdriver – Bosch, Black & Decker, Challenge or similar.

Maplin:
Telescopic antenna (Item code QT34M).

Other items:
Nylon kitchen cutting board (local hardware store).
Brass sheet (for optional home-made fingerstock) and brass mounting bracket (local model shop).
Sundry screws, nuts, bolts, 10 x 8mm brass bar, split-pin (junk box).

To aid construction the following tools will be needed:
Set of hole borers for cutting collars and plugs from nylon board.
Set of metric taps.
Fretsaw, Rat's tail file, flat file, Mitre block and saw, screwdrivers, range of HSS drills.

Fitting the Threaded (Allthread) Rod

Refer to **Figs. 3** and **4** before fitting the Allthread rod. Cordless screwdriver kits normally have an adaptor piece that inserts into the hexagonal drive shaft in order to extend their reach. This makes a convenient location for the Allthread, which should be a loose fit in the adaptor. A 6mm (¼in) diameter threaded rod was used. Screw two nuts of appropriate size onto the rod and run them up the rod for an inch or two. These serve as the lower stop-nuts and are adjusted later. Insert the end of the Allthread into the adaptor piece and drill a 2mm hole right through the adaptor and threaded rod, push in a small split-pin and bend the ends up to keep the rod from coming out. The rod should

Fig. 3: Threaded rod with stop nuts and screwdriver adaptor.

not be a tight fit in the adaptor but free to move slightly.

Cut another nylon plug to fit tightly into the base of the coil tube as you did for the top. Drill three retaining holes equally spaced and countersink as before but don't tighten up yet. Drill out this plug dead centre with a clearance hole through which the Allthread can pass freely then cut a short length of brass bar (I used 10 x 8mm square section), just wide enough to 'sit' across the end of the coil former, see Fig. 4. Drill a hole in the dead centre of the brass bar and tap a thread to take the Allthread. Then drill two 4mm clearance holes either side of the centre-threaded hole to take the retaining bolts, which will clamp the bar to the nylon plug. Line up the bar and plug, mark where the retaining bolts are and drill through the plug. Clamp the bar to the plug with M4 bolts and nuts. Run the Allthread into the bar and add two further stop nuts on the other end for later adjustment. Insert the assembly into the base of the coil tube so that the ends of the brass bar are resting on the sides of the tube, line up the retaining holes and screw up using countersunk brass screws as you did at the top. Ensure that

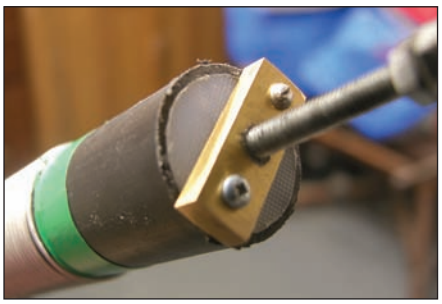

Fig. 4: Coil former base showing threaded rod fixing.

this plug is squared accurately and check that the coil former doesn't swing violently from side to side as you turn it on the rod, which would give a very jerky rise and fall motion when under motor power.

The Base Tube

The coil retracts or deploys from the base tube under motor power. The base tube was a 915mm (3ft) section of aluminium tubing for lightness and strength. It doesn't have to be aluminium but can be brass bedstead, copper tubing or chrome-plated water wastepipe. The wall thickness should be a minimum of 2mm and the inside diameter large enough to accept the cordless screwdriver and the coil, with clearance all round. An inside diameter of 2in (51mm) will accommodate most of the screwdriver units available. At this point, three identical nylon plugs need to be cut to fit tightly into one end of the base tube. These three plugs are drilled centrally then sandwiched together using a 10mm steel bolt and nut, which will also serve to mount the antenna onto the base plate later. Fit a plain washer and shakeproof washer under the nut to stop any tendency for rotation when the base tube is tightened onto the base plate. Drill a hole through the plug parallel to the mounting bolt, to thread the motor drive cable through.

Referring to **Fig. 5**, insert the nylon plug-and-bolt assembly into one end of the base tube so that two 'wafers' of the nylon plug are within the tube and one wafer protrudes. This is necessary to electrically isolate the base tube from the base plate. Drill eight equally spaced retaining holes through the metal tube casing and into the middle wafer of the three. Countersink the holes where the retaining screws will be inserted. The illustration shows small cuts made into the end of the base tube and the retaining screws placed between alternate cuts. These screws must not contact the central bolt. We have yet to fit the motor so remove the nylon plug and place it to one side.

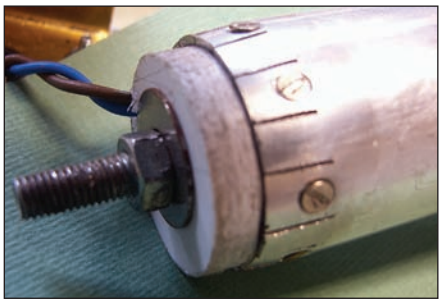

Fig. 5: The base tube mounting plug.

Preparing the Motor

Open the cordless screwdriver casing and remove the batteries. Take care that the gearbox does not detach from the motor or you will have to spend time replacing all the gears! Unsolder all the leads from the battery to the switch and from the motor. Remove all of the switch mechanism. Across the two terminals on the back of the motor solder a 0.01μF disc ceramic capacitor. Connect at least one metre of twin cable to the terminals and route this out through a hole drilled in the end of the handle of the screwdriver casing. If you have space in the casing, insert as many ferrite beads as you can onto each lead to assist in choking stray RF and suppressing any interference from the motor. Close up the casing and test the motor at its recommended voltage using a bench power supply. Usually that will be between 2.4 and 3.6V depending on how many battery cells you extracted. If all is well, check that the modified screwdriver will insert into the base tube. If the switch housing on the screwdriver casing fouls the base tube, cut and file it away until it slides in centrally.

Place a short length of PVC pipe over the handle end of the screwdriver casing. The diameter of this sleeve should allow for a tight sliding fit but make sure that the motor still goes right into the metal base tube. Any slack can be taken out using insulating tape around the handle and elsewhere along the casing as necessary. The aim is to tightly fit the screwdriver into the base tube with the drive-end perfectly centralised to accept the adaptor on the end of the Allthread. The diagram, **Fig. 6**, gives a clearer idea of the setup.

Once the motor is lined up and firmly slid in the base tube, fit one retaining screw each side. These screws are inserted through the base tube either side of the screwdriver and into the PVC sleeve covering the handle. Insert the nylon end plug and bolt, passing the motor wires through the hole you previously drilled through it. Make sure the plug is square and in line with the previously drilled fixing

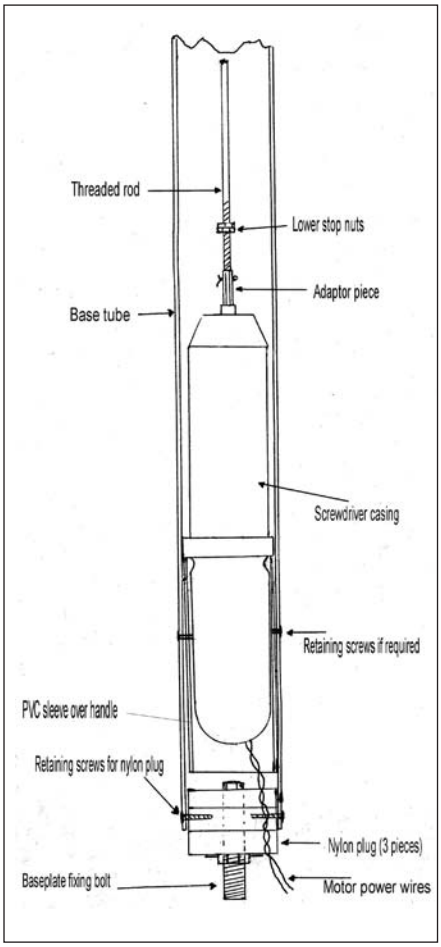

Fig. 6: The arrangement for fitting the motor in the base tube.

holes. Lock in place using eight short countersunk woodscrews and tighten up. Now is a good time for a quick function test so insert the coil and Allthread assembly in the other end of the base tube and locate the adapter in the drive end of the motor. If everything is centralised, there will be no problem in lining up and locating the adapter. Holding the other end of the coil centrally, energise the motor with its normal working voltage and make sure the coil moves up or down freely without excessive waggle or binding on the Allthread. Now is also a good time to adjust the lower stop nuts so adjust them at the point the coil is fully retracted into the base tube. In use, that should be at the topmost turn of the windings. When you have the correct adjustment, remove the coil and threaded rod and lock the stop nuts together.

Fitting the Fingerstock

Next prepare the fingerstock to encircle the top of the base tube so that it makes contact with the turns of the coil as it deploys. During construction, there was no beryllium-copper fingerstock available in the UK and the postal charges from the US were prohibitive but I eventually tracked down a supplier in Slovakia via eBay. Some readers may have their own supply from other projects but it is perfectly possible to make your own from brass shim and even better if you have access to a silver-plating bath or Plating Silver Cleaner solution. I used '10 thou' thick brass shim from the local model shop and cut off a strip approximately 20mm wide and long enough to go around the circumference of the base tube. Drawing a score line down the centre of the shim, cuts were made inwards from the long edge down to the score line. The width between cuts was 5mm, which resulted in a row of 'tabs' like that shown in **Fig. 7**.

Fig. 7: The fingerstock after initial preparation.

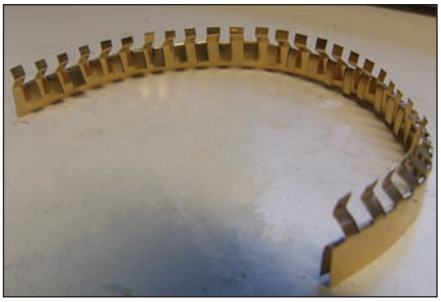

Fig. 8: The completed homebrew fingerstock.

Fig. 9: The fitted fingerstock, secured with M4 nuts.

Fig. 10: Beryllium copper fingerstock.

Next, I bent every other tab back on itself, parallel to the uncut area, this part eventually being located around the top edge of the base tube. The remaining tabs were flattened so they were all parallel, then shaped as shown in **Fig. 8** with a slight waist and bent slightly outwards at the top. Ensure they all look the same.

Place the fingerstock around the top of the base tube and cut to length. If you are using a brass or copper base tube, the fingerstock can be soldered on using a suitably robust blowtorch. Alternatively, the fingerstock and tube can be drilled through and threaded with an M4 tap. M4 bolts can then be used to retain the fingerstock in place along the top edge on the base tube. File the bolts flush inside the tube or use pop-rivets instead. The final product should resemble that in **Fig. 9** or **Fig. 10** if you are using the beryllium-copper finger-stock.

Insert the coil and Allthread rod assembly into the base tube from the top, taking care not to bend the fingerstock out of shape. Locate the drive adapter in the motor and adjust the contact of the fingers on the coil windings. You may need to bend in the 'fingers' in which case use your thumbnail in the waisted portion to ease the fingers until they make reliable contact but not too tight. Apply some power to the motor and ensure that the coil can move up and down freely on the rod without catching and bending the fingers. Check the electrical continuity between the base tube and the coil turns as they appear from the tube to ensure a consistent and reliable finger contact along the whole length of the coil. With the coil fully extended (on its last turn) you can now adjust the top stop-nuts, which will again require removal of the coil assembly. The stop nuts at this end can only be locked together after removal of the plug that carries the Allthread from the end of the coil tube. After locking the nuts together, reassemble into the end of the coil tube. This part does not have to be removed again.

Reinsert the coil assembly into the base tube and engage with the motor drive. Give yourself a pat on the back. You have now completed the lower part of the antenna.

Next Month

I will complete the description of the project next month. This month, though, I have included a parts list in the sidebar so that you can start to collect together the necessary hardware and tools.

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A Remote-Controlled Homebrew Screwdriver Antenna Part 2

David Beard G8FMX completes last month's Screwdriver antenna project.

The cover tube is made from clear acrylic with a wall thickness of 3mm and provides mechanical and weather protection for the coil. Its length should be about 150mm shorter than the base tube and its inside diameter should be sufficient to slide over the base tube with 3 to 5mm clearance. It is attached to the top of the PVC coil tube with a nylon collar cut from the chopping board, **Fig. 1**, and secured by three countersunk woodscrews placed around the edge. The acrylic tube is then fitted over the collar and should be a fairly tight fit. Adjust the cover tube with the coil fully inserted in the base tube, ensuring there is an equal gap all the way round, then drill three countersunk retaining holes around the top and into the collar. Start by using a 1.0 or 1.5mm drill-bit in a hand drill. Acrylic may crack and split if too large a drill is used to start with. Finish with a 2.0 or 2.5mm drill and countersink the holes by hand-twisting a larger drill bit in the hole. Secure with three countersunk brass woodscrews but don't over tighten. A plastic cover (I used the lid from a tin of de-icer) can be placed over the top of the cover tube and the collar to finish off the job neatly as in **Fig. 2**, which also shows a simple anti-twist device to dampen out any tendency for the coil to rotate as it moves up and down (see later description).

Preparing the Whip Sections

If you intend to use this antenna for mobile operation, the whole whip section should be a springy steel rod since it would be unwise to use 15mm pipe sections in that situation. One knock from a low branch would destroy the antenna in short order! Because the antenna has been designed primarily for fixed or portable operation, the use of the pipe sections adds some rigidity and wind resistance. There are two pipe sections topped by a telescopic whip. Each of them is 790mm (31in) in length, which includes a straight 15mm compression joint placed at one end of each pipe and screwed up tight with the olive in place. The top section is a telescopic whip 1.32m (52in) long and this is used for coarse tuning in conjunction with the coil inductance. For attachment to the copper pipe, I soldered the base of the telescopic whip to a straight 15 to 10mm brass reducer. I used a brass sleeve to obtain a tight fit into the smaller end of the reducer. For protection, the soldered joint was then covered with a small plastic cone slid down the whip to the brass fitting. At the other end of each pipe section is an olive and nut ready for attachment to the coil top or the second pipe. The photo, **Fig. 3**, shows how the couplings are arranged. When you have completed the

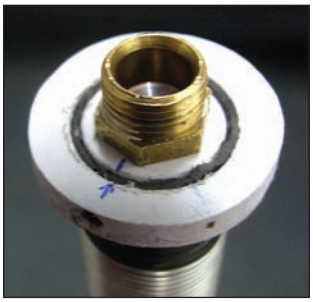

Fig. 1: The top of the coil with the cover flange fitted.

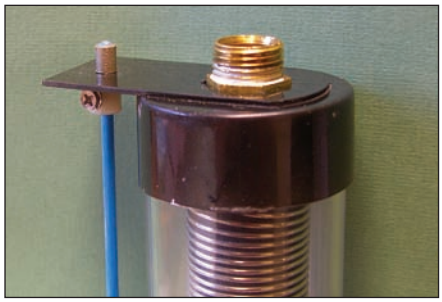

Fig. 2: With the protective cover and anti-twist arrangement.

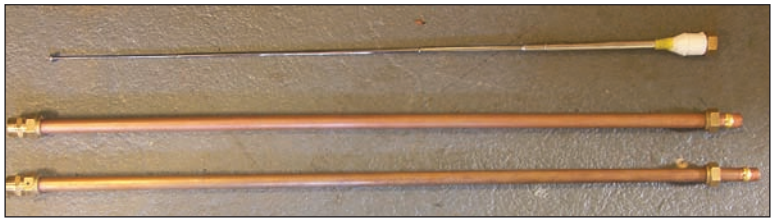

Fig. 3: The three antenna sections, showing couplings.

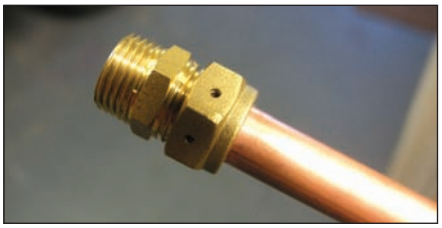

Fig. 4: A close up of one of the holes drilled for the capacity hat.

Fig. 5: The capacity hat loops.

three sections, assemble them together and check they are straight.

In the compression joint at the end of one of the pipes (it doesn't matter which), drill a hole right through each of the flat faces on the hexagonal flange as shown in **Fig. 4**. These holes should be a clearance fit for the 14SWG aluminium wire to be used for the capacity hat loops.

Capacity Hat

The first patent for the use of a capacity hat was issued to **Sir Oliver Joseph Lodge** in 1898. For further information on the benefits of capacity loading there is a brief but good resume by **G4FGQ** at: **www.smeter.net/antennas/short-top-hat-loaded.php**

and by **K0BG** at: **www.k0bg.com/caphats.html**

Conventional wisdom dictates that the capacity hat must be mounted at the top of the antenna as far from the coil as possible so its efficiency is not degraded. The larger the capacity hat, the more effective it can be. However, practical considerations such as wind loading force a more pragmatic approach, the wind resistance of the antenna being traded off against a lower mounting position for the capacity hat wires. I arranged three detachable lightweight aluminium wires in a closed cloverleaf mounted at about 1.53m (5ft) above the coil with an effective diameter of 1.22m (4ft). Subsequent measurements indicated that this mounting position provided a wider bandwidth and required a lower inductance to resonate than with the whip alone.

Referring to **Fig. 5**, the capacity wires are formed from three 1.55m lengths of 14SWG aluminium florists' wire bent round to form a broad leaf-shaped loop. They fit into the holes drilled around the compression joint on the 15mm copper pipe whip section and should be a tight, self-supporting push fit. It doesn't matter whether they are not accurately in line because there is bound to be some upward or downward tilt on individual loops.

At frequencies above 18MHz, the capacity hat provided no practical benefit since, at that point, capacitance is too high and inductance required for resonance so low that the loading coil just 'runs out of turns'. Using the whip alone at these higher frequencies brings back the requirement for inductive loading and, in combination with adjustment of the whip length, the antenna can tune to the 6m band with half a turn inserted and a whip length of 77cm (30in). A good match as defined by low SWR and low residual reactance (X) can be obtained at the points of resonance.

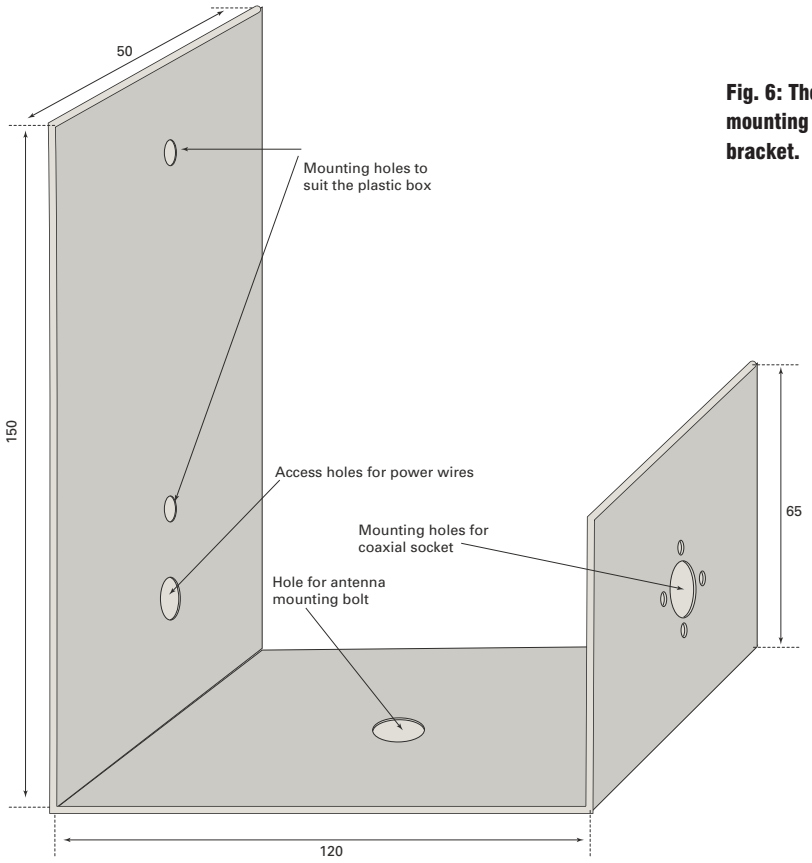

Fig. 6: The mounting bracket.

Preparation and Mounting of the Antenna

Before the antenna is mounted on the metal base, provision is made for a suitable connection of the RF feed. This may be done by means of either a solder tag drilled and tapped in the base tube or as, in this case, a copper or brass band around the lower end of the base tube, secured with a 55mm galvanised hose clamp. The copper band has a small pigtail on which to solder a wire from the centre of the SO239 socket. Next, a brass or aluminium U-bracket needs to be bent as shown in **Fig. 6**. I used a piece of 1.2mm thick brass, 50mm wide by 335mm long. On the shorter side of this bracket the SO259 socket should be fitted with four nuts and bolts while the other side provides a pillar on which to mount a 165 x 85 x 55mm plastic project box (Maplin) housing the wireless remote control unit and associated circuitry. The bracket will also accommodate the antenna's mounting bolt and a grounding strap.

I made the grounding strap from a short length of copper braid soldered to a large copper washer, drilled to accept the antenna's mounting bolt and ready for subsequent fitment under the brass bracket. The free end of the braid was screwed onto an earth rod clamp bolt.

For mounting the antenna, an aluminium panel 3mm thick, of sides 600 x 600mm, was used as the base plate. This size was a trade-off between portability, weight and a reasonable degree of mechanical stability while providing at least limited potential for capacitive coupling to ground. The plate was drilled in the centre to accept the antenna mounting bolt and a second hole was drilled about 200mm away from the centre through which a 4ft copper earth spike could be placed. When set up for use, the end of the earth spike should protrude about 50mm above the base plate to accommodate the clamp bolt.

Apply a large washer to the mounting bolt, followed by the brass bracket and earthing braid washer. Insert the bolt through the base-plate centre hole and fit another large washer. Apply the nut and tighten but not so much as to rotate the bolt inside the nylon plug. Ensure there is no electrical contact between the base plate and the base tube.

It is essential to provide extra stability for the base tube by means of a 'steady-post', which should be non-metallic. The photo, **Fig. 7**, shows the detail.

The top of the support bracket was cut from the nylon board then screwed to the top of a 25mm diameter wooden dowel secured to the base plate with an aluminium bracket. Prior to fixing, the

nylon board requires a hole to be cut in it that is 2 to 3mm larger than the acrylic cover tube diameter. The collar thus formed allows a sliding fit over the tube. The inner edge of the hole can be lined with felt or similar to take up any slack and to allow smooth movement during traversing of the coil.

Solder tinned copper wire from the coaxial socket centre pin to the RF feedpoint at the bottom of the base tube. The 'earthy' side will be in contact with the brass bracket, base plate and the earth rod. To add radials subsequently, the edges of the base plate can be drilled and fitted with small bolts and tags to accommodate these wires. However, in the design here, only earth rods are used.

A Word About Grounding

After hours scouring the internet and books on this subject, I came across a publication from *Signal*, March 1988, by a member of the US military and detailing an effective method of rod-earthing for field antennas. The 'take-home' message was as follows:

"Ground rods were driven into the earth at various depths and the resultant ground resistance and RF impedance measurements recorded. The tests were repeated with ground rods mechanically connected in series and driven to different depths in the earth. The use of four series-connected ground rods, driven only a foot or two into the earth, provided the most efficient ground system. These improved field grounding techniques should be applicable to amateur radio stations, particularly during Field Day operations". **Lt Col US (ret) David Talley W2PF**.

I decided to adopt the series-connected approach with four ground rods of lengths 4ft, 2ft and two at 1ft arranged around the base plate. They were daisy-chained together with automotive earthing braid, the longest rod protruding through the base plate. All subsequent measurements and trials were conducted using this setup. As a future experiment, the effect of two 10m rolls of 25mm galvanised chicken wire laid out in a cross could be tried, the antenna being placed at the centre. In conjunction with the grounding rods, this should improve the performance noticeably.

Base Matching Coil

For frequencies up to about 10MHz, some form of matching between the RF feedpoint and ground is required to obtain a low SWR. This can be done either by the use of two switched capacitors for

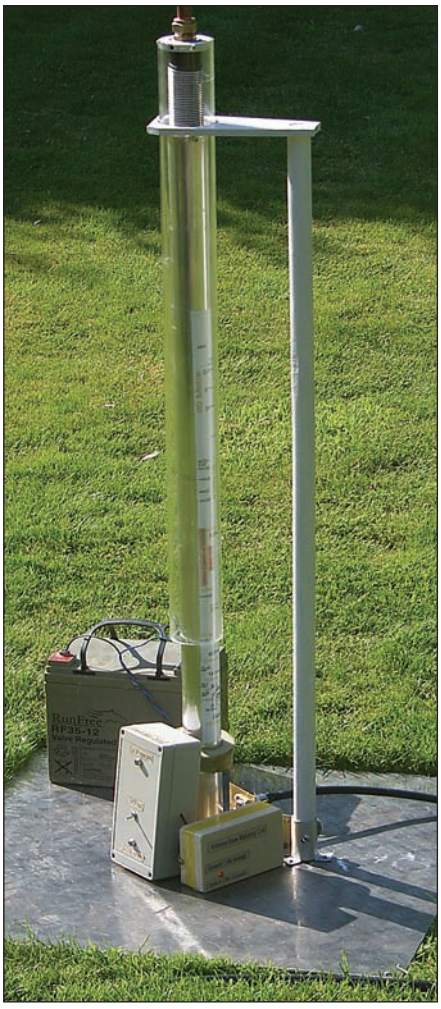

Fig. 7: The 'steady post' for the antenna base tube.

the 80 and 40m bands (usually around 800pF and 400pF respectively) or by a small inductor of approximately 0.5 to 1.5μH. The latter method is preferred for this antenna since it provides a DC path between the baseplate and the antenna and facilitates convenient remote selection of the optimal tap point for the 80 and 40m bands.

The photo, **Fig. 8**, shows the matching coil, which consists of 9 + 9 turns of 16SWG enamelled wire, centre tapped on a 1in former. One side of the coil is stretched to about 1.5in while the other side is compressed but individual experimentation is needed to optimise the SWR at say 3.55 and at 7.05MHz. The coil is mounted in a small plastic box and a 12V SPDT relay is mounted near the centre tap. The 'common' relay contact is grounded onto the brass mounting bracket and the 'NO' contact is connected to the centre tap of the coil. Energising the relay will cause only half of the coil (wider spacing) to be in circuit for the 40m band. 80 and 60m require the entire coil to be in circuit. Above 10MHz the entire inductance can remain in circuit since it plays no further part. The 'hot' end of the matching coil is taken to the SO259 socket centre

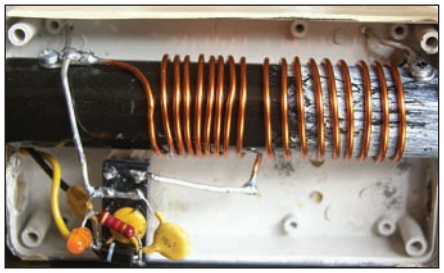

Fig. 8: The base matching inductor.

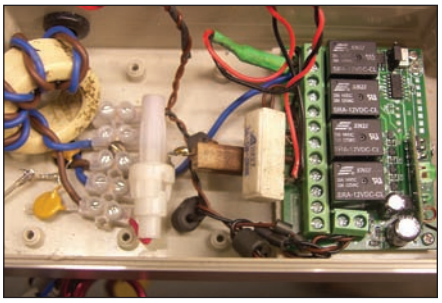

Fig. 9: The remote control receiver and relay board.

pin or to the RF feed point on the base tube (whichever is closer). Place an LED across the relay coil to indicate when the coil tap is selected. The actuating relay for the centre tap is a 'slave' and is energised via one of the relays in the remote controller, under the control of a button on the key-fob. The housing box can be conveniently secured to the baseplate with a couple of self-tapping screws.

Remote Controller

The direction and speed of the coil's movement in and out of the base tube and the base matching coil tap can be controlled with the key fob, which activates a four-channel wireless remote-control unit. This unit is mounted in a plastic box as shown in **Fig. 9**, secured to the longer side of the brass bracket at the base of the antenna. The wireless controller board runs on 12V DC and consists of a receiver unit operating in the 315MHz licence-free band, a decoder for the button codes and four relays with connector strips, which may not be arranged logically. For this reason, relay closure must be identified for each button using a continuity meter on the screws of the connector strip. Mark the relays A through D and determine which are the NC and NO contacts for each, making a note of the arrangement. There is also a jumper pin on the controller board and the position of this must allow the relays to latch such that the relay stays activated until the same button is pressed again. The schematic in **Fig. 10** shows the wiring diagram. The power leads to the motor are suppressed by means of clip-on ferrites and decoupling capacitors and a 1.5A fuse should be inserted into the positive battery line. I also mounted two

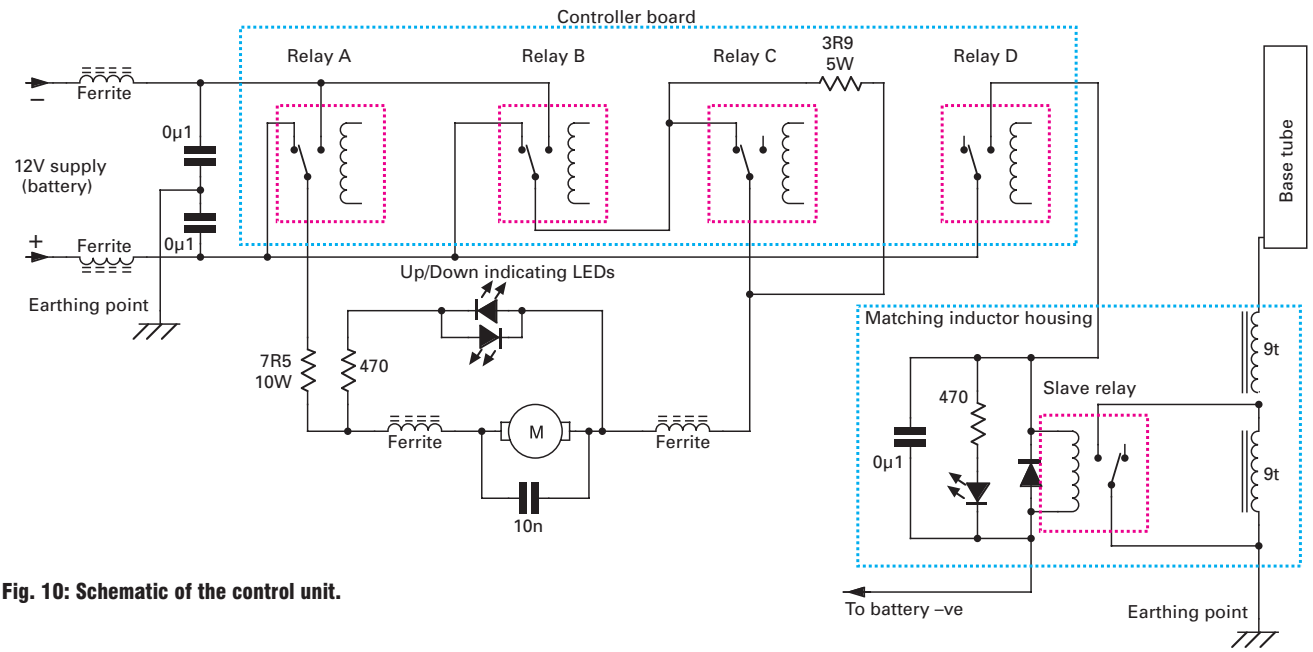

Fig. 10: Schematic of the control unit.

LEDs on the front of the box to indicate when the motor was activated either up or down. The leads to these LEDs were also given a few ferrite beads. Because the motor runs at about 2 to 4V, the 12V supply must be reduced. For my setup, a 7.5Ω 10W resistor in series with one of the motor leads provided the right speed. A slower speed for fine-tuning was added by using the relay controlled by button C to switch in or out an additional 3.9Ω of series resistance. Fit an on/off switch on the front panel to isolate the DC to the controller. Buttons A and B control the up and down movement of the coil and button C the speed while button D is wired to switch in the slave relay in the base-matching box. The power source I used was a 12V gel-cell battery positioned next to the antenna, thus removing the need for leads back to the shack or operating position. Battery leads should be individually suppressed with ferrite, as should the leads to the slave relay in the base-matching box. The key fob operated reliably over about 25m but should not be operated when the antenna is RF fed.

When you have completed wiring up the controller according to the schematic, check it and apply 12V from a bench PSU fitted with current limiting, in case of trouble. If all is well, press A on the key fob and the coil should go either up or down. Press A again to stop it. If it goes down when A is pressed, reverse the motor power wires. Ensure that button B causes the coil to wind in and A causes it to rise. The two LEDs should light, one for each direction. Activating button C will cause the motor to run at approximately half speed. Press D to activate the inductor centre tap for the 40m band, making sure that its indicator LED lights. Turning off the power will reset the logic and all the relays. Replace the PSU with the 12V battery. The power requirements are very modest (under 1A with the motor energised).

Calibration Scale

To aid location of the correct coil position for different bands, I contrived a frequency scale that consisted of a laminated paper scale fixed to the metal base tube. The bottom of the acrylic cover tube was used as the indicator. This somewhat crude but nevertheless effective method gave good repeatability. Temporarily fix a strip of paper to the base tube and set up the antenna with the four earth rods inserted (or your preferred grounding system). Then attach the whip sections at full length and deploy the coil almost all the way out. Now, using an antenna analyser (I used the Rig Expert AA54), adjust the coil for minimum SWR at 3.5, 3.6, 3.7 and 3.8MHz, with the entire base-matching coil in circuit. Adjust the turns of the matching coil by compressing or stretching to obtain the best match or compromise match between SWR and lowest residual reactance (X). You should obtain an SWR better than 1.3:1 over the 80m band so when you are happy with the result, mark the positions on one side of the paper strip at each frequency. Repeat this process for all bands at your favourite frequencies, ensuring that at 7MHz (and, possibly, 10MHz) the centre tap of the base-matching coil is selected and adjusted. Above that frequency all of the matching coil is in circuit but has no effect. The scale becomes cramped the higher in frequency you go. Make sure you adjust the length of the whip according to **Table 1**. The telescopic section is always in use and individual adjustment will undoubtedly be necessary. When complete, repeat with the capacity hat fitted, marking the other edge of the paper. You will find that the number of turns for resonance is much less with the capacity hat fitted and above about 14 to 18MHz the inductance required becomes too low to be usable so the hat can be removed. On completion, make a reference mark on the paper scale and the base tube for later alignment, then remove the scale and make a neater job of it. I scanned the paper scale into a graphics program (PaintShop Pro) for this purpose. Print out the final copy scale (same size!). It can be covered with adhesive clear plastic film before being relocated more permanently to the base tube using the reference mark.

Table 1: Antenna Length Guide.

Freq (MHz)	Total whip length (in)	Sections
3.5	114	3
3.6	114	3
3.7	114	3
3.8	114	3
5.3	104	3
7.1	104	3
10.1	104	3
14.1	104	3
18.15	90	2
21.2	90	2
24.95	72	2
28.5	60	1
29.5	60	1
51.0	30	1

And Finally

When the coil is moving up or down, the weight of the whip section (pipe plus telescopic section) and the light grip of the

fingerstock normally prevent the assembly from rotating. However, there may be a tendency for the coil to slip occasionally when the motor is providing full torque and rotating quickly. While it does not affect the operation, it can be a nuisance but is easily damped out. Refer again to Fig. 2 and note the plastic extension on the cover cap, which carries a plastic rod. This passes through a clearance hole in the nylon collar at the top of the steady post and moves in or out as the coil rises and falls. Providing the plastic rod is reasonably rigid, any tendency of the coil to twist is removed.

The stop nuts on the threaded rod are an emergency-only measure and it is advisable not to use these for stopping the coil routinely or the whole mechanism may jam because the motor develops considerable torque. Use the key fob and only move the coil to the point of interest on the calibration scale.

You have now completed the antenna – great work!

Testing the Antenna in the Real World

I set up the antenna on the back lawn with four earth spikes daisy-chained together and connected to the base plate. It was about 10m from the house and any shrubs or trees. For testing, I included the station's portable choke balun (19 turns of RG213 on a drainpipe former of 100mm diameter). This was sited close to the coaxial socket and connected with a short lead but was not used for measurements at 10 or 6m. RG213 cable was then run from the choke balun about 12m to the garden bench used for testing and was within easy range of the wireless controller. To start with, the whip was at its maximum length of 2.9m (114in) and the coaxial feeder was connected to the AA54 analyser.

The results are shown in **Table 2** without the capacity hat fitted. The data includes SWR, R, X, whip length, coil turns and the approximate 2:1 SWR bandwidth. This was then repeated as far as possible with the capacity hat in place, **Table 3**. In general, at resonance, acceptably low values of X coincided with lowest SWR although not always. Ideally, reactance (X) should be zero at resonance but measurement and other errors provide little confidence in that value. In practice, a close compromise between lowest SWR and lowest X value has to be made. The 2:1 bandwidth values probably have the worst confidence limits of all the measurements and increased more than expected as frequency increased, indicating possible deficiencies in coil efficiency (*Q*).

Screwdriver Antenna Properties (no capacity hat)						
Freq MHz	SWR	R	X	Length of whip section (inches)	Coil turns	Bandwidth KHz (2:1 SWR)
3.5	1.01	50.1	-0.9	114	151	41
3.6	1.12	52.5	-5.1	114	145	47
3.7	1.03	48.0	7.4	114	137	51
3.8	1.08	53.7	-1.4	114	128	52
5.3	1.09	53.2	-3.3	104	71	77
7.1	1.05	53.0	0.3	104	40	175
10.1	1.11	45.0	0.9	104	20	490
14.1	1.07	46.6	-0.7	104	10	1184
18.15	1.06	50.1	-2.7	90	5.5	2175
21.2	1.06	48.9	2.5	90	3.5	3136
24.95	1.05	48.6	-1.9	72	3	3524
28.5	1.07	53.4	-0.5	60	3.5	3978
29.5	1.05	49.1	-2.7	60	2.5	5007
51.0	1.14	47.5	-6.2	30	0.5	13317

Table 2

With the capacity hat in place, the measurements confirmed that the inductance required for resonance at a given frequency was drastically reduced, in line with theory and as indicated by the number of turns exposed. Additionally, the 2:1 SWR bandwidth was increased proportionately at all frequencies up to 18MHz after which the added capacitance was excessive and had to be removed. Comparing the values of SWR, R and X at resonance revealed rather variable but nevertheless acceptable values with and without the added capacitance of the hat. It was also felt that these results indicated that the grounding efficiency was passable but not brilliant.

Screwdriver Antenna Properties (with capacity hat at 1.58m)						
Freq MHz	SWR	R	X	Length of whip section (inches)	Coil turns	Bandwidth KHz (2:1 SWR)
3.5	1.06	46.6	0.4	114	105	67
3.6	1.03	51.3	0.6	114	99	67
3.7	1.08	53.7	-1.3	114	93	71
3.8	1.10	54.6	1.8	114	89	72
5.3	1.27	44.7	9.9	104	47	108
7.1	1.08	54.4	0.3	104	24.5	287
10.1	1.10	48.2	4.7	104	12	856
14.1	1.16	43.2	1.3	104	4	2046
18.15						
21.2						
24.95			Not relevant			
28.5						
29.5						
51						

Table 3

Contacts were subsequently made around the UK and Europe with the antenna at ground level using four series-connected ground rods. If you construct this antenna, give it a good trial under your own working conditions. I would be very interested in your results.